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Studies on Optoelectric Properties of Chemically Deposited Transition Metal Doped CdS Thin Films

Research proposal submitted

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Introduction:

Thin film semiconductors play an important role in the development of modern technological devices for variety of applications. Thin film shows significant changes in spectroscopic properties as compare to bulk material. CdS is II-VI group compound which have great importance in photovoltaic and optoelectronic devices because of high transmission coefficient and wide band gap. LEDs, FET, Transistors, detectors, semiconductor lasers are formed by doping CdS with other semiconductors [1-3]. Wavelength corresponding to band gap falls in the visible region thus, CdS is promising material for LEDs and Lasers [4]. It is commonly used in CuS, CZTS solar cell in combination with other semiconductors and for the window material [5-8]. Besides this physical and optoelectrical properties of CdS can be further modified by doping transition metal such as Cu, Fe, Ag, Ni, In, Zn for advanced functional devices. Transition metal refers to the element in the d block of periodic table and is partially filled its d orbitals. Doping process modulates the semiconducting behavior of optoelectronics devices tuning their optical and electrical properties. Cu is used in the back contact formation of CdTe absorber layer and in CdS for window layer [9]. Doping Copper with CdS could lead to large variation of the resistivity, band gap energy, photo electrical properties and also altering the type of semiconductor [10-12]. Another important transition metal is Ni having ionic radius of (0.72 Å) which is less as compare to Cd^{2+} (0.97 Å). Thus it is easily incorporate in CdS that will reduces the electrical resistivity of CdS and thus modifying structural and optoelectrical properties of CdS thin films [13]. Various thin film properties also dependent on deposition method and preparative parameters. There is different deposition technique having its importance for the special purpose application. Chemical deposition such as chemical bath deposition, spray

pyrolysis, SILAR is the popular deposition method in researchers for preparation of thin films of II-VI group semiconductors.

Literature Review:

A A. Aboud et al. [14] Studied the pure and Cu doped CdS Thin films and reported that for 2 to 6% Cu doping, particle size was found to decrease from 28 nm to 25.4 nm. Morphological study shows increase in surface roughness from 25nm to 31nm with Cu-6% doping. Energy band gap decreases from 2.43 eV to 2.39 eV with increase in Cu content. However structural data shows there is no phase changes with the Cu doping.

O. I. Diaz-Grijalva et al. [15] studied Cu-doped CdS thin films by chemical bath deposition and ion exchange, the study reported that after Cu doping particle size was reduced by 15 nm as that of undoped CdS thin films but the film thickness was unaffected by doping . optical study reveals that low doping of Cu increases the band gap energy but higher doping concentration of Cu produces the opposite effect . This is argued that the doped Cu ions are not on the surface of the thin film but are merged into CdS material. This suggests that proper doping of Cu ions can manipulate the required energy band gap for different applications.

Yi Deng et al. [16] studied the effect of Cu doping on optoelectrical and microstructural properties of CdS thin films. CdS doping hindered the recrystallization of the nano sized grains in deposited films also fill factor decreases for CdTe solar cell fabricated with Cu doped CdS window layer.

K. Deka et al. [17] Studied effect of transition metal (Fe, Co, Ni, Mn) doping in CdS by chemical co-precipitation method at room temperature, they found that There is no change in crystal phase due to doping, however there was slight increase in their crystallite sizes. XRD

study shows lattice parameters and lattice volumes decreases after doping which is attributed to smaller radius of dopant as compared to Cd^{2+}.

S. Yılmaz et al. [18] Studies Ni doped CdS thin films with reference to structural, morphological, optical and photovoltaic performance , XRD study shows that doping of Ni produces the deterioration in CdS crystal structure. Also morphology of doped film changes as grain size decreases from 17 to 10 nm for doping of Ni at 0 to 7 at%. Band gap increases from 2.98 to 3.39 eV V, which is due to the existence of strong quantum confinement effect. Current density–voltage (J–V) characteristics of CdS-based device gives power conversion efficiency of 0.296%. in this study, for 1 at% of Ni doping power conversion efficiency is enhanced to 0.663%. However, with increasing Ni-doping up to 3 at% and 5 at%, power conversion efficiency values recorded as 0.131% and 0.208%, indicating a deterioration in PCE value of cells, which might be due to the less efficient exaction dissociation at the interface. Further increase of Ni-doping to 7 at% led to an efficiency value of 0.417%, which is still lower than that of 1 at% Ni-doped CdS-based device.

A. Mercy et al. [19] in the study of Ni doped CdS quantum dots, observed that the crystallinity of the nanoparticles increased with increasing Ni concentration. Diffraction peaks of Ni doped CdS show a small shift towards higher 2θ values as compared to pure CdS. The size of nanocrystallites decreases from 6-7 to 1.5-3 nm. The crystal structure is unaffected with changing the doing concentrations except the broadening of the peak. The optical absorption edges of the prepared Ni doped samples are found to have blue shift due to the high quantum confinement effect of the nanoparticles. this may be due to the reduction of the particle size upon doping.

A Firdous et al. [20] Studied Electrical and optical parameters of pure and Ni doped CdS quantum dots, they found that Ni substitution in the CdS leads to increase the conductivity of the composition. Moreover, doping of impurity atoms by chemical substitution generally brings disorder in the system, which may tend to delocalize the carriers at the doping site. The Optical absorption studies show that the absorption edge shifts towards blue region for both CdS and Ni-doped CdS of the as prepared nano-materials with respect to bulk (CdS) indicating that effective band gap energy increases with decreasing particle size.

R. Murugesan et al. [21] studied Fe/Mn doped CdS thin films, structural study showed that doping of Fe, Mn and Fe+Mn doped Cds thin films, mixed phases of cubic and Hexagonal turned towards the cubic phase of CdS only. Also Morphological, Photoluminescence, Optical parameters are studied with Fe, Mn and Co-doping .

Abstract:

Present research work deals with the study of transition metal doped CdS thin films prepared by chemical bath deposition method. Thin films will be prepared with different dopant concentrations, bath time and temperature.

Deposited films will be characterized using different techniques such as XRD, SEM, EDAX, UV, etc. to study the effect of dopant on structural, morphological, optical and electrical properties for photovoltaic applications.

Objectives:

Objective of this work is to prepare the thin films of CdS and transition metal doped CdS thin films by suitable chemical deposition method and characterized the prepared thin films for organized study with reference to the variety of applications.

Hypothesis:

a) Preparative parameters such as temperature, deposition time, doping concentrations will grow a good quality film.

b) Structural and morphology of the thin film is dependent on doping elements.

c) Doping of transition metal will reduce the band gap, increases the crystallinity of the films. Also it will alter the behavior in positive direction.

Importance of the study:

Many researchers have studied the structural, morphological, optical, electrical, photoluminescence properties of Cds and some transition metal doped semiconductors. Literature survey tells about the alteration of above parameters as a result of doping and synthesis techniques. Thus, special purpose devices can be fabricated by doping suitable substance in the controlled manner for the efficient photovoltaic devices. Also transition metal doped CdS shows decrease in energy band gap and conversion of semiconductor type from n to p type and vice-versa. Power conversion efficiency of the photovoltaic devices can be increased by proper doping material. Thus it is necessary to study this effect of changing preparative parameters on different properties of the semiconductors used in technological devices.

Methodology

Synthesis of thin films:

In this work suitable chemical deposition method (chemical bath deposition, Spray pyrolysis, SILAR) will be used to deposited pure CdS and transition metal doped thin films on the glass substrate. Chemical deposition commonly used for thin films deposition as these are simple, economic and simple than the physical deposition methods. Thin films with different preparative parameters like temperature of substrate, pH, deposition time and doping concentrations will be synthesized.

Characterization:

a) Film thickness: Thickness of prepared thin film will be measured by simple weight and difference method.

a) X- ray Diffraction (XRD) : crystal structure, grain size, lattice constants will be obtained from the XRD data. This data will compared with the ICDD (JCPDS) data.

b) Scanning Electron Microscopy (SEM) : Morphology of pure and doped thin films will be compared from SEM images.

c) Energy Dispersive X-Ray (EDAX) Analysis: This characterization technique will examine the presence of the required element and its composition.

d) Optical characterization: with the help of UV – visible spectrometer absorption, transmittance, band gap will be calculated.

e) Electrical characterization: I-Characterization with the help of two point probe/ four point probe will be carried out.

f) Other related characterization : Thermoelectric power measurement, J-V charecteristics, Microstrain, Dislocation density etc. and some related study will be reported.

Chapter Scheme:

Chapter 1 : Introduction

Chapter 2: Literature Review

Chapter 3: Deposition and characterization Techniques

Chapter 4: Synthesis and characterization of CdS thin films

Chapter 5: Synthesis and Characterization of transition metal doped CdS thin films

Chapter 6 : Results and Discussion

Year wise plan of work:

First Year:

- Review of previous work done
- Selection of doping transition metal
- Optimization of preparative parameters to synthesize thin films

Second year:

- Synthesis of pure and transition metal doped CdS thin films
- Characterization of synthesized thin films
- Publication in journal/ conferences

Third year:

- Analysis of data obtained in characterizing films.
- Thesis writing

References:

[1] G.S. Vorobjov, V.O. Zhurba, A.S. Krivets, J. Nano- Electron.Phys. 2 No 4, 47 (2010).

[2] W. Wondmagegn, I. Mejia, A. Salas-Villasenor , H.J. Stiegler , M.A. Quevedo-Lopez , R.J. Pieper, B.E. Gnade, Microelectronic Engineering 157, 64-70 (2016).

[3] P.J. Sebastian, Solar Energy Materials and Solar Cells 44(1), 1-10 (1996).

[4] K. Hasanirokh, A. Asgari, S. Mohammadi, J. Eur. Opt. Soc.-Rapid Publ. 17-26 (2021).

[5] P. M. P. Salomé, J. Keller, T. Törndahl, J. P. Teixeira, N. Nicoara, R. RibeiroAndrade, D. G. Stroppa, J. C. González, M. Edoff, J. P. Leitão, S. Sadewasser, S. Sadewasser, Solar Energy Materials and Solar Cells, 159, 272-281(2017).

[6] C. Ma, X. Lu, B. Xu, F. Zhao, X. An, B. Li, F. Yue, J. Jiang, Y. Chen, L. Sun, J. Chu, Journal of Alloys and Compounds, 817, (2020).

[7] T. Sinha, L. Verma, A. Khare, Applied Physics A, 126, (2020).

[8] A. B. Wong, S. Brittman, Y. Yu, N. P. Dasgupta, P.Yang, Nano Lett., 15, 4096 4101 (2015).

[9] Z. Bai, J. Yang, and D. Wang, Appl. Phys. Lett. 99, (2011).

[10] V. Singh, P.K. Sharma, P. Chauhan, Materials Characterization, 62, 43-52(2011).

[11] El-Naim A, Solieman A., Shaaban E. R., Materials in Electronics 31 (4) 3613-3621(2020).

[12] Alzaid M.,. Mohamed W. S, El-Hagary M., Shaaban E. R., Hadia N. M. A., Optical Materials 118,(2021); https://doi.org/10.1016/j.optmat.2021.111228.

[13] I.S. Yahia, I.M. El Radaf, A.M. Salem, G.B. Sakr, J. Alloys Compd. 776, 1056 (2019).

[14] Ahmed A. Abouda,, Ayan Mukherjee , Neerish Revaprasadu , Ahmed Nagaty Mohamed, journal of Material Research and Technology 8(2),2021–2030(2019).

[15] O. I. Diaz-Grijalva et.al., Journal of Materials Science: Materials in Electronics 31(6):1-9 (2019).

[16] Yi Deng, Jun Yang, Ruilong Yang, Kai Shen, Dezhao Wang, and Deliang Wang, AIP Advances 6, 015203 (2016); doi: 10.1063/1.4939817.

[17] K. Deka, M.P.C. Kalita, , Journal of Alloys and Compounds (2018), doi:10.1016/j.jallcom.2018.04.323.

[18] Yılmaz, S., Tomakin, M., Ünverdi, A. et al., J Mater Sci: Mater Electron 31, 12932–12942 (2020). https://doi.org/10.1007/s10854-020-03846-1.

[19] A. Mercy a, A. Jesper Anandhi b, K. Sakthi Murugesan a, R. Jayavel c, R. Kanagadurai a, B. Milton Boaz, Journal of Alloys and Compounds 593, 213–219 (2014).

[20] Arfat Firdous ,D. Singh , M. M. Ahmad, Appl Nanosci 3,13–18(2013): doi: 10.1007/s13204-012-0065-0

[21] Murugesan, R., Sivakumar, S., Karthik, K. et al. , Appl. Phys. A 125, 281 (2019). https://doi.org/10.1007/s00339-019-2577-x.